Journal of Conventional Weapons Destruction

Volume 23
Issue 1 *The Journal of Conventional Weapons Destruction Issue 23.1*

Article 16

April 2019

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John Fardoulis
Mobility Robotics

Xavier Depreytere
Humanity & Inclusion

Emmanuel Sauvage
Humanity & Inclusion

Pierre Gallien
Humanity & Inclusion

Drones in the Desert: Augmenting HMA and Socio-Economic Activities in Chad

by John Fardoulis [Mobility Robotics], Xavier Depreytere, Emmanuel Sauvage, and Pierre Gallien [Humanity & Inclusion (HI)]

Figure 1. The team approaches a minefield for the first consumer drone cartography flight over a confirmed hazardous area (CHA) in Chad. *All images courtesy of the authors.*

Funded by the Belgian Directorate-General for Development and led by Humanity & Inclusion (HI) under the auspices of the National Mine Action Centre, Haut Commissariat National au Déminage (HCND) in Chad, the Odyssey2025 Project explores ways to accelerate land release for the local population with the combined use of small drones, new survey methods, and mobile data collection. Project partners include Mobility Robotics, Dynergie, InZentive, and Third Element Aviation. A practical, field-driven approach is being undertaken together with partners in the PRODECO project, (MAG) Mines Advisory Group, and Fondation Suisse de Déminage (FSD).

Online literature is available that discusses the pros and cons of different types of drone airframes, and how the mapping process takes place. A good starting point for further reading is the FSD Drone Portal: www.drones.fsd.ch; Geneva International Centre for Humanitarian Demining's (GICHD) recently launched e-learning portal: https://gichd.litmos.com, which provides information about how to integrate drones into humanitarian mine action (HMA); and the articles featured within *The Journal of Conventional Weapons Destruction* on the use of drones in HMA.[1–8]

On 24 January 2019, the authors created the first drone cartography of a minefield near the village of Amoul, in the Faya-Largeau area of northern Chad. The goal of this first mission was to validate how drones can provide better situational awareness of suspected hazardous areas (SHA), confirmed hazardous areas (CHA), and zones clear of contamination in desert conditions. This campaign is part of a broader trial to determine how small drones can help to accelerate the land release process and gain operational efficiencies. The next stages include assessing the effectiveness of drone data to tighten the definition of SHA/CHA borders, indicate where land might be cancelled or reduced, and achieve more targeted technical survey. Other practical benefits will also be explored by combining drone and HMA expertise during embedded field trials.

MATERIALS AND METHODS

SMALL UNMANNED AERIAL SYSTEMS

Where possible, the authors have tried to leverage the data capture potential from relatively low-cost, commercial off-the-shelf (COTS) drones. The concept of operations presented here takes COTS equipment and software, and combines known processes and defined indicators to generate actionable operational intelligence. Rather than try to reinvent the wheel, these tests strive to get better mileage from existing equipment and software that is already accessible to the community.

A starting point was using indicators of direct evidence listed in 07.11(5.3) Land Release of the International Mine Action Standards, with signs of contamination including visual observation of explosive ordnance (EO) parts, craters, detonations by animals, mine signs, fencing, EO accidents, or incidents where the location of the event could be accurately determined. Initial indicators of an absence of contamination include roads in use, land used for certain types of agriculture, and footprints from large animals. Work is ongoing with HI technical staff, and the national mine action center (MAC) to validate further direct and indirect indicators. The January mission trialed new equipment such as the first sub-1 kilogram drone with variable optical zoom: the DJI Mavic 2 Zoom (M2Z).[9] Video goggles were also tested, to determine how useful a more immersive live experience would be during inspection and reconnaissance operations. For example, an explosive ordnance disposal (EOD) specialist might want to direct the pilot to fly closer to or around

DJI MAVIC 2 ZOOM

Take-off weight	905 grams
Max flight time	25 minutes
Max range	More than 2 km
Size (diagonally)	354 mm
Max Windspeed	~35 kph

Figure 2. Small but powerful, the DJI Mavic 2 Zoom captured all the data in this article.

objects.[10] These devices can also be useful during improvised explosive devices disposal (IEDD) operations.

SOFTWARE AND APPS

The cartography flight-planning process involved importing a SHA or CHA polygon from the MAC Information Management for Mine Action (IMSMA) database into a drone autopilot app before leaving for the field. Each MAC has a database of SHA or CHA points and polygons, collected years or decades prior. If a polygon does not exist, a flight plan covering a greater footprint than the area of interest will be programmed. Three different flight-planning apps were tested.[11–13] Poor internet connectivity was a particular challenge while working in the desert, and the plan needed to account for that.

DATA PROCESSING

Images from mapping flights were processed with COTS photogrammetry software to create orthomosaic, topographic, and digital surface model (DSM) outputs.[14] Data outputs were analyzed and post-processed in geographic information system (GIS) software using ESRI's ArcMap application.[15] Data sets were also provided to HI and MAC technical staff as high-resolution, offline, Google Earth layers—making GIS data viewable on every laptop, prompting discussions regarding how to prioritize the deployment of technical survey assets.

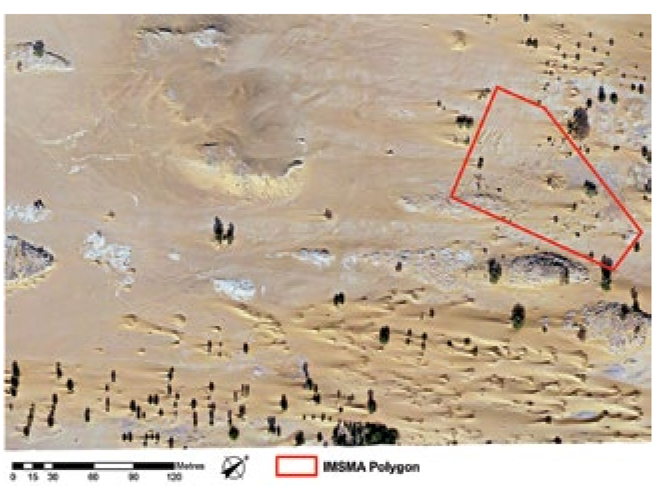


Figure 3. Cartography of the second test location shows a CHA surrounded by mixed terrain and natural features such as sand dunes, rocky outcrops, and sparse vegetation. The resolution captured was approximately ten times that from civilian satellites.

MISSION PLANNING

Two modes of operation were used:

- Relatively low-altitude inspection flights, remaining stationary at times to hover, circle, and zoom, capturing snapshots of evidence points during inspection and reconnaissance missions.
- Programming mapping missions to automate data capture in a set way to generate cartography and topographic information.

During the first trial, the purpose of drone inspection missions was for planning to gather evidence for EOD specialists to make judgments regarding the cause of explosions at accident locations and discuss the probability of nearby hazards. Mapping missions were used to create an area overview of the entire CHA, looking for patterns and to function as a base map for operational planning.

HUMAN INTELLIGENCE

Human intelligence from mine action specialists is just as important as an ambitious data-capture strategy and can provide answers to "so what" questions regarding features identified in cartography and inspection data. For example, identifying a pattern of recent tire tracks across a CHA can impact operations in different ways, depending on interpretation. Tire tracks indicate that members of the public are driving through the CHA, which might signal a need to better mark the perimeter with warning signs, or conduct mine risk education (MRE) in the area, perhaps elevating the priority of technical survey or clearance of that site to prevent accidents. Or perhaps tire tracks hint that a portion of the polygon is clear of contamination because an explosion did not occur when a vehicle drove through, suggesting an adjustment of CHA borders. This example also provides insight into how drone data can influence different aspects of HMA activities ranging from MRE to clearance. Collaborative research will continue during the length of the one-year project, determining which features are most useful and documenting outcomes under field conditions.

GROUND SIGN INDICATORS

The true value of drone data will be determined by how it can augment operations on the ground: capturing evidence-points, features of interest, patterns, man-made anomalies, or other clues that provide hints of what might (or might not) be under the ground. Moreover, by providing a better understanding of the terrain, drones can help identify hazards, access points, or elements that might pose challenges for operations.

In some cases, it will be beneficial to re-survey a SHA or CHA to gain additional knowledge such as patterns not visible from a ground-level perspective, helping target technical survey or clearance assets by directing them to hot spots first. In other cases, EOD specialists might deem that CHA borders can be redefined. Working closely with the chief of ops and technical field managers (TFM) is important to align strategies with the end users of drone data products.

Hence, a key objective during the first mission was to collaboratively develop a catalogue of ground-sign indicators and prove how using cues from the catalogue can influence operations on the ground. Creating a framework for generating valuable, actionable intelligence is central to process innovation.

TEST LOCATIONS

Field tests took place in three locations, providing a mix of terrain, ground signs, and objects to inspect or map. The first site was a minefield (Figure 4 and Figure 5) where demining teams were conducting technical survey in a CHA. The second CHA location (Figure 3) was a battle area clearance site where a destroyed vehicle was carrying 122 mm rockets. Imagery from these two post-conflict sites will be added to a ground-sign database to calibrate against in the future. The third test site (Figure 9) was a training location for HI's GCS-250 demining machine to create slope maps for planning mechanical operations.[16]

RESULTS

GROUND-SIGN INDICATORS

In Figure 4, Images 1 and 2 show how overhead photos of ground signs can be captured by an operator standing 200 meters away, outside of the CHA. Image 1 is evidence of a camel accident, with a blast crater next to it, and possibly a second crater under the animal bones. Image 2 is evidence of a vehicle accident, with the blast area possibly under the left front wheel.

Image 3 shows how cartography can help to join the dots between Image 1 and Image 2. If you draw a line in Image 3 between the two accidents, it appears that they occurred along an old road. A pattern is visible on the ground, which may be weathered signs of its presence. Piecing all the information together suggests that the road may have been mined because of its strategic nature during the conflict. Or perhaps this man-made pattern relates more directly to the conflict, or subsequent post-conflict operations? Whatever the case, based on imagery analysis, more targeted technical survey is required in that area.

Tests showed how inspection flights can distinguish fine details from different perspectives for a bigger picture, with cartography capturing the whole polygon (Figure 5) to look for patterns.

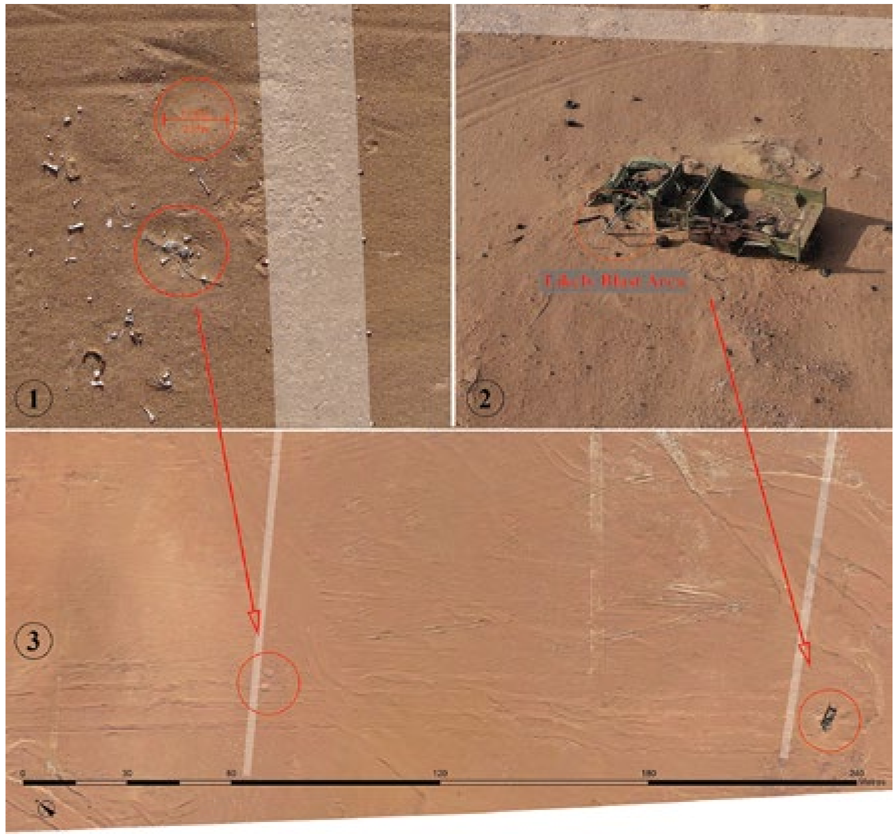


Figure 4. Image 1 shows an example of a ground sign indicator, an animal accident, and craters (red circles). The white shading shows a technical survey lane (visible in all images) that was opened to investigate. Image 2 shows another ground sign indicator: a vehicle accident. Image 3 shows a consumer drone cartography output. By drawing a line between the two red circles in this image, one can see possible signs of an old road, which is another indicator. Note the technical survey lanes for access to accident spots, shaded in white.

The crater next to the animal accident in Figure 4, Image 3 is visible from a higher (cartography) flying altitude, but individual bones are difficult to see from that height. Figure 4 demonstrates how a combination of imagery from inspection and cartography flights can complement each other. Personnel can also return and inspect hot spots more closely if technical advisors want more information.

EVIDENCE-BASED SURVEY

These results provide field examples of how high-resolution imagery and cartography can assist the HMA process. A starting point was resurveying CHAs currently being worked on by ground teams to identify indicators and ground truth data, calibrate resolution, quality-check mapping capabilities of a sub-1 kilogram drone, and gain validation from EOD personnel. The data also shows how several different observations can be linked together, which can increase confidence levels for decision making.

SPEED

It only took a few hours on-site to capture all the raw data regarding the minefield, proving how fast reconnaissance and cartography data capture can be compared to opening technical survey lanes to examine hot spots. After the raw data was captured, cartography took about a day to process per site back at the base.

MORE TECHNICAL INSPECTIONS

Being able to move a camera in three-dimensional space and capture imagery from directly above means scope for more technical interpretations of data. From the drone data, the authors determined that the size of the crater next to the animal bones in Figure 4 Image 1 to be 2.15 meters in diameter. Such information can affect planning by indicating whether the explosion was from an anti-personnel or anti-tank mine.

HIGH-RESOLUTION TERRAIN MAPPING

Mapping terrain and other elements of the natural environment can help many aspects of HMA operations. However, the process of creating maps from drone data is more involved than the process for inspections. Thus, field validation in-country was important, e.g., proving that it was viable to map sand dunes. Figure 6 shows the results of a sand dune mapping test, with Image 1 being a high-resolution orthomosaic map that shows how sand dunes can be recognized visually. Image 3 of Figure 7 shows how a topographic map was created by post-processing a DSM from drone data. Although it was initially unclear, the reflectivity and texture of sand did not make a difference, and standard techniques were fine. Mapping sand dunes is of interest as they tend to move, affecting access to sites by covering/uncovering contamination.

The ability to map roads was also field-proven, which will be useful because demining roads is a priority in many locations.

The usefulness of being able to spot rocky outcrops, unfavorable terrain, and other hazards for demining machines was validated, in association with the mechanical operations team (Figure 3 and Figure 9). Data was captured (Figure 9) to help plan how the drone and demining machine can work together. Figure 9 shows a slope map, indicating different terrain inclines at the machine training site (top right, green area).

The idea was to identify locations where the demining machine can excel, and map out hazards in advance, so that the amount of time and money

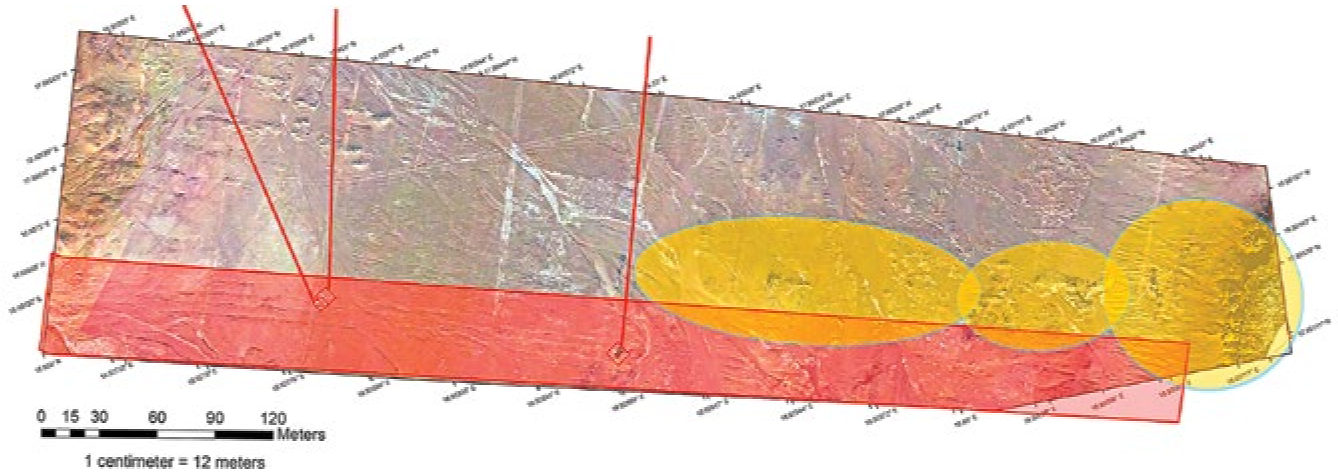


Figure 5. Digitized high-resolution cartography of the complete CHA polygon from Figure 4. This was analyzed closely by technical specialists to discuss operational implications of features identified by the aerial intelligence.

spent on repairs are reduced. There are many ideas to field test across multidisciplinary teams next mission.

QUALITY OF MICRO DRONE ZOOM

Results of variable optical zoom tests from the M2Z were positive, with sample data from 25 meter and 119 meter heights shown in Figure 7 and Figure 8.

Original photos from the drone are shown in Figure 7 Images 1 and 3, and in Figure 8 Images 5 and 7. Differences that the two times zoom makes in object detail and image footprint can be seen in columns on the left.

Sections of each photo were reviewed at very high magnification on a PC to compare fine details. For example, a difference in sharpness can be seen along the edges of the rocket body and in the details of the human footprints when comparing Figure 7 Images 2 and 4 at a 25-meter height. Improvements in detail and sharpness are also visible when comparing the zoom to standard perspective in Figure 8 Images 6 and 8 at a 119-meter height.

Testing also took place to review the quality of an additional variable two times digital zoom (total four times) in high-definition (HD) video mode, i.e., the ability to zoom from 24 millimeters to 96 millimeters (equivalents). The quality was acceptable, and helped capture more detail without having to fly closer.

One of the key findings was that up to four times variable zoom in HD video mode (two times for photos) was easy to operate while flying. The operator can adjust the zoom by moving a wheel on the controller, providing greater utility than other drones in that class. The option to capture a more tailored perspective while in flight will simplify workflow back at the base, negating the need for post-processing analysis of features of interest.

The outcome from these tests was to validate that the M2Z as an effective tool with additional inspection capabilities.

VIDEO GOGGLES

Glare can be an issue in the desert, so enclosing an observer's view and placing the display close to his/her eyes means a more immersive experience, with much greater magnification. Several EOD specialists tried the video goggles as part of a combined drone/EOD team scenario, and feedback was positive. One of the best tests will be during EOD spot tasks next mission. A more immersive, live experience will allow a specialist observer to inspect evidence of hazards from a safe distance and better assess a site in real time. Gaining a high-quality camera view, moving in three-dimensional space, flying around objects, viewing from different perspectives/angles ranging from up-close inspection to a broad footprint of the area from a higher altitude, which will help save time. Searching a broader area around the perimeter is often faster from in the air than on the ground. CHAs can be several hours drive from the base, meaning that becoming more productive per visit will improve efficiency.

The video goggles also proved to be a useful educational tool, allowing deminers to gain a birds-eye perspective, as if they were flying inside the drone. Dozens of people got to try.

For more information about results from the January field mission, including flying videos and sample data see: www.mr-au.com/chad.

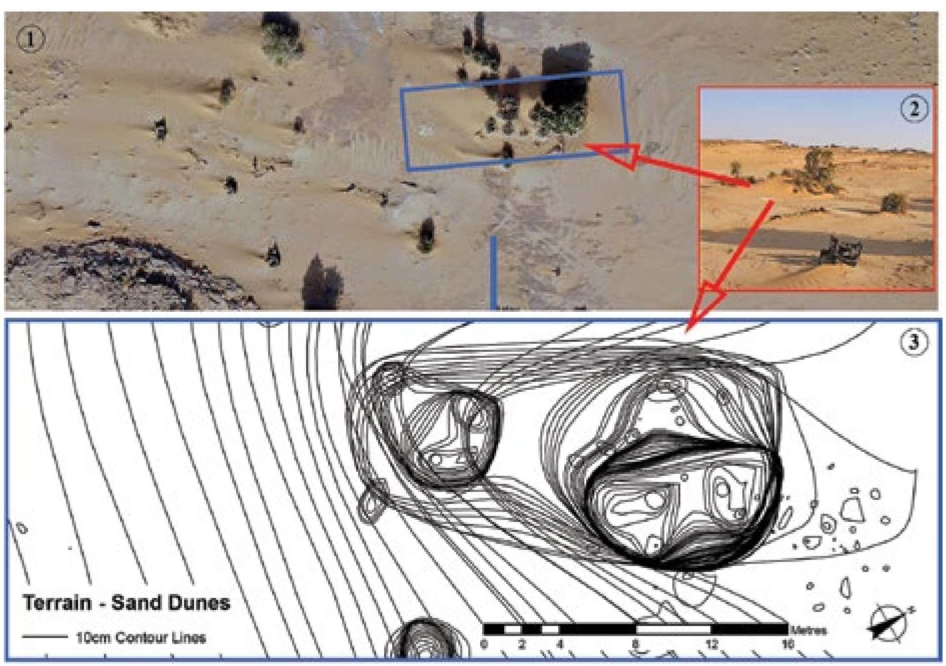


Figure 6. Image 1 is a high-resolution optical (orthomosaic) map showing the ability to identify sand dunes visually. Image 2 is a ground reference photo taken of nearby sand dunes to check against cartography (Images 1 and 3). Image 3 is a high-resolution terrain map of sand dunes from data captured during the same consumer drone flight as for Image 1.

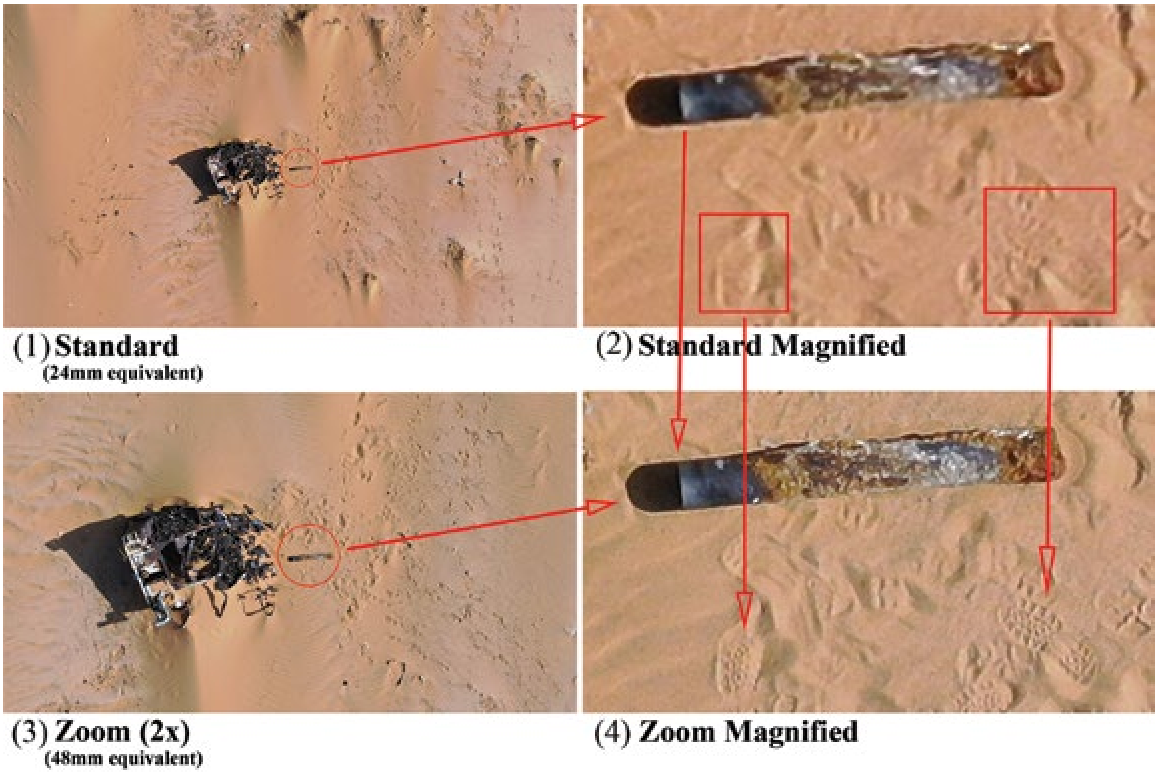


Figure 7. Two photos taken from the M2Z at a height of 25 meters: Images 1 and 3. Image 1 is at a standard wide-angle perspective. Image (3) was taken at the same height but used the two times optical zoom. Image 1 and 3 show the differences between the area captured and enlarging features of interest. Image (2) is a magnified version of the standard perspective to compare fine detail on a computer. Image 4 is the optical zoom photo, magnified on a computer. You can see differences in quality in the magnified images, particularly the edges of the rocket casing and detail in human footprints.

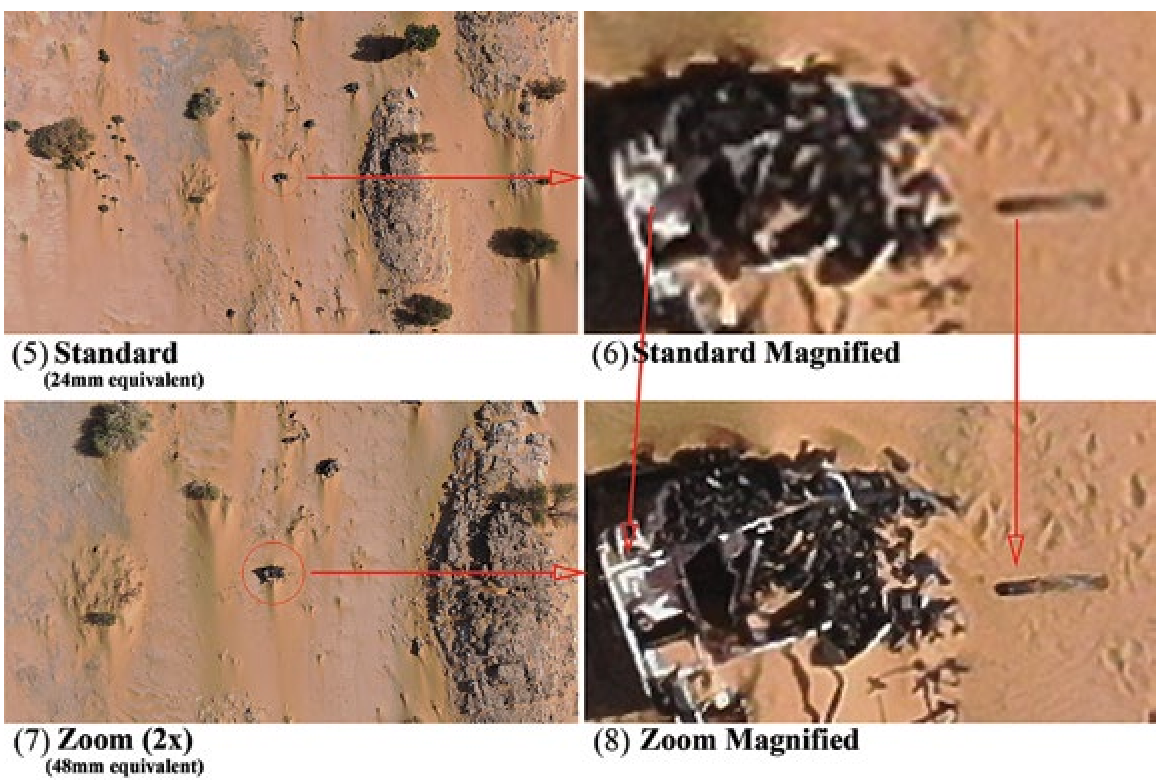


Figure 8. Two photos, Images 5 and 7 taken at a height of 119 meters using the same methodology as above. Differences in the rocket casing can be seen in Images 6 and 8, plus clearer lines and sharper edges in the vehicle remains in Image 8.

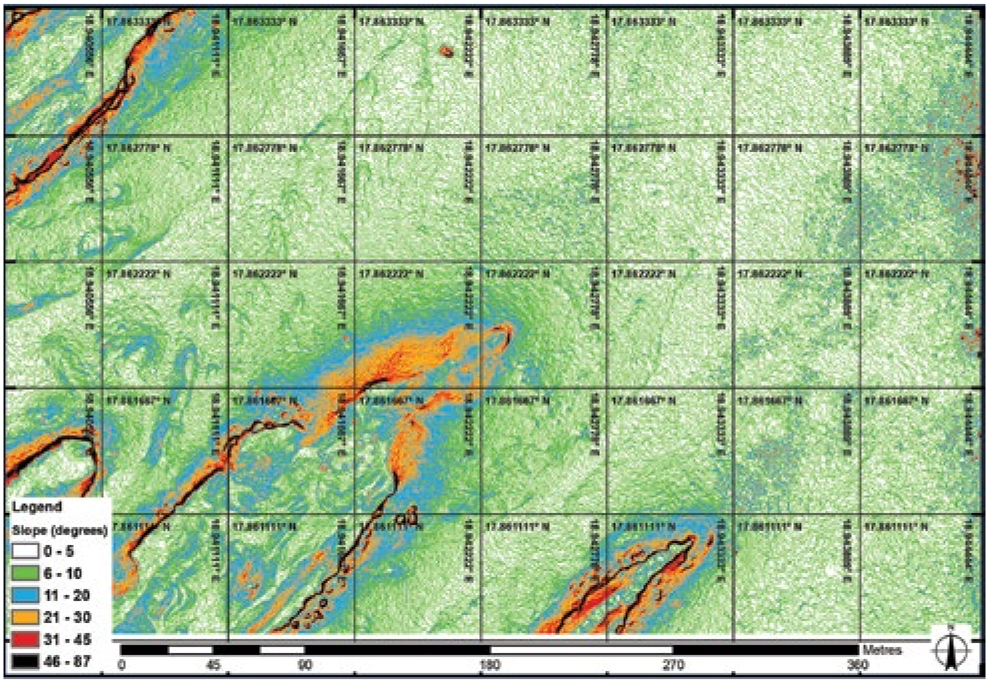


Figure 9. Shown is an example of a customized consumer drone demining machine operations map indicating the slope of terrain. It can be taken into the field electronically, or as a laminated hard copy. As most demining machines have a limit regarding the gradient at which they can work, slope maps can help operational planning.

LESSONS LEARNED

The ability of small consumer quadcopter drones to remain stationary by hovering presents a lot of potential opportunities for inspections and reconnaissance, particularly when a zoom camera is included. In addition to traditional HMA tasks, micro models have the added value of being well-suited for inspections of damaged buildings in Iraq, Syria, and Libya, as they are used increasingly during IEDD operations, looking for small objects, such as wires. Examples of inspections are shown in Figure 4 and Figure 7.

Most drones have a wide-angle lens as standard, which is often better for mapping flights. However, as the M2Z illustrated, the flexibility to zoom produced both acceptable mapping quality and offered improved results for inspection and reconnaissance. A minimum standoff distance from the ground, obstructions or possible hazards will need to be specified in drone standard operating procedures, meaning that zoom capabilities from an altitude or standoff distance of 15–30 meters will be useful. Being able to dynamically zoom using the M2Z is practical and comes at virtually no extra cost. An additional element that the authors will monitor is heat dissipation, as the electronics seemed to heat up more while in operation than slightly larger drone alternatives. There are restrictions regarding the size of drones allowed to be used in HMA operations in some countries. Being a micro size, the sub-1 kilogram model fits within such restrictions.

A lessoned learned relating to Figure 4, was that a drone is a fast reconnaissance tool, compared to otherwise having to open technical survey lanes for inspecting suspected hot spots; i.e., flying in from outside the CHA to capture evidence points. This doesn't negate the need for human assets on the ground but could help to gain better efficiency from more targeted technical survey. Another lesson learned was the power of being able to digitize site information (Figure 5). This led to greater collaboration, with inspection data and cartography reviewed simultaneously; by TFMs, the chief of operations and the regional technical advisor.

Results from the first field campaign suggest that progress can be made in innovating processes, gaining synergy by blending HMA and drone expertise to collaboratively find ways of making an impact. The equipment and software used for this project were purely COTS, meaning that it's all about applied usage and know-how.

A few operational questions arose along the way, such as the policy regarding wearing personal protective equipment (PPE) while operating near SHAs or CHAs. Project members determined that it is up to the site manager (e.g., a TFM) to have the last say where and when PPE needs to be worn.

LAND-RELEASE

One of the foundations of land release is the non-intrusive gathering and checking of as much evidence as possible, with drones being an asset to help leverage or augment the value of other assets by providing additional site-specific data. Dronts will not replace deminers on the ground in the foreseeable future, and they won't replace human intelligence. What they can do is provide additional targeted information to help gain better productivity from human, mechanical, and animal assets.

Decisions regarding each site need to be made on a case-by-case basis; however, gaining confidence in indicators that better pinpoint evidence will help target technical surveys and clearance, perhaps starting from hot spots and working outward. Ideally, discussions regarding fade out from hot spots inside CHAs might lead to new ideas regarding targeted technical survey that saves time and resources. Gaining confidence in indicators that suggest the absence of contamination, most likely combined with other information could lead to an acceleration in the amount of land being cancelled or reduced. Decisions need to be risk and evidence-based, combining data from various sources, and include both ground and aerial assets, as an area may not be deemed hazard-free purely based on no visible signs.

HUMANS IN HMA

Removing explosive hazards is important, but the process of doing so can be slow and expensive. Being embedded in remote demining operations meant ties to the community. Meeting local villagers and representatives from the regional government helped teach project members about the needs of the local population, who are the actual beneficiaries of HMA work. What do they believe is most important? The road or shortcuts linking the north to N'Djamena?

BEYOND RESEARCH

Even though there are research components, the scope of this project extends further because an operational framework for drone usage needs to be implemented. Together with the HCND, HI and Mobility Robotics are launching humanitarian drone operations in Chad for the first time. There are no formal regulations regarding drone usage, meaning that approvals are required from multiple ministries/authorities, including the Ministry of Defense and Aviation Authority. Importing equipment can be a challenge, and delays in customs clearance are not uncommon.

Building capacity by training pilots is another goal, as recruiting the right candidates improves sustainability once the Odyssey2025 project concludes. Dront equipment has been selected to provide local teams with field kits that are fit for purpose. Information technology equipment is being procured, including powerful laptop computers, a desktop processing workstation, and archival-storage system to handle the large volume of data generated. These must be located at the base in northern Chad, as self-sufficiency is required due to poor internet connectivity. Workshops will be held for government ministries and other humanitarian organizations in Chad to prompt thoughts regarding drone potential in other areas.

Logistics are also important. For safety, a minimum of two vehicles must travel together when venturing into the Sahara Desert, with a medic often required as a precaution. If multiple drone teams are deploying simultaneously to five locations, they require ten off-road vehicles, 10 drivers, five medics, five pilots, five observers, and sharing the resource of a technical specialist, such as a TFM. Such elements may affect the scalability of drone operations.

CONCLUSIONS AND FUTURE WORK

Results from the desert field trial helped to establish proof that, when tailored effectively, imagery can help augment other assets and suggest ways to gain operational efficiencies. Two modes of operation were established: inspection and cartography. Work will continue to increase the depth and breadth of the ground-sign catalogue, and field test the validity of each indicator.

Time and resources permitting, a satellite data study may take place, conducting a trade-off analysis using drone data for calibration to ground-truth space data.

During the next two field campaigns, a number of different categories of drones and sensors will be tested in a desert environment, with capabilities matched to mission objectives.

Ideally, enough sample data sets will be captured from in the field to use as a proof of concept for future initiatives utilizing artificial intelligence, deep learning and machine vision techniques for automated analysis. Lessons learned will be shared through in-depth case studies.

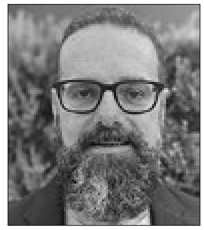
Capacity-building will commence during the next mission, providing equipment, teaching Chadian pilots how to operate drones and about the processes required to convert data into actionable intelligence.

See endnotes page 71

ACKNOWLEDGEMENTS

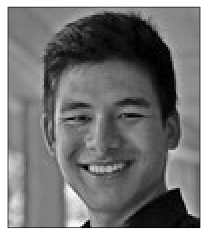
The authors would like to thank the donor, the Belgian Directorate-General Development for making the project possible. Special thanks are in order to the people of the HCND for their support and for making pre-testing a reality. The GICHD and FSD deserve thanks for joining the technical steering committee for the Odyssey2025 Project. We'd like to thank the following people for their contributions and assistance; Seydou Gaye, Victoria Memel, Jason Mudingay, Gary Toombs, HI staff in Belgium, Lyon and Chad, and the MAG, FSD and OCHA teams in Chad. Feedback from reviewers is appreciated. The University of Bristol deserves thanks for providing access to software and super-computing resources.

JOHN FARDOULIS
Project Partner,
Mobility Robotics (AU) & Fardoulis Robotics (U.K.).



John Fardoulis is a consumer drone and small unmanned aerial system (sUAS) specialist on the HI Odyssey2025 Project in Chad and is also a Visiting Research Associate at the University of Bristol (U.K.). Having worked in both academia and as a commercial sUAS service provider (with CAA accreditation in the U.K.), he is in a unique position to add value at every level of sUAS operations. John has a Bachelor of Business from the University of Western Sydney (AU) and a masters in Aerospace Engineering from the University of Bristol (U.K.).

XAVIER DEPREYTERE
Project Manager
Humanity & Inclusion (HI)



Xavier Depreytere recently joined Humanity & Inclusion (HI) in 2018 after working in industry as an automation project engineer. He is currently in charge of the strategy and the coordination of the HI Odyssey2025 Project in Chad. Xavier holds a masters in biosystems engineering from the University of Mons, Belgium.

EMMANUEL SAUVAGE
Director of the Armed Violence Reduction Division
Humanity and Inclusion (HI)

Emmanuel Sauvage has an industrial logistics management background and enrolled in humanitarian action in 1994 in ex-Yugoslavia. He first joined Humanity & Inclusion (HI) in 2002. For the past 17 years, he has held senior and advisory positions for HI and other international organizations/agencies in the field of humanitarian mine action and armed violence reduction. He has had direct exposure to information management, quality, land release (clearance and surveys), risk education/management, victim assistance, and advocacy. Optimistic and enthusiastic by nature, he has diversified experiences and is very supportive of innovative and creative solutions.

PIERRE GALLIEN
Director of the Impact, Information & Innovation Division
Humanity and Inclusion (HI)

Pierre Gallien is an agronomist but was keen to enrich his curriculum with complementary training in management (IAE), epidemiology (CESAM), and strategic foresight (CNAM). During his 25-years experience in the humanitarian field, he has held many technical (technical coordinator, Head of Knowledge Management division) and operational (geographical manager, mission director) positions for Action Against Hunger, Solidarités International, and Humanity & Inclusion. This eclectic experience in humanitarian action has allowed him to better understand the specific constraints of the different positions, but also to underline the importance of cross-sectoral approaches.